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(71)Applicant : **NIPPON STEEL CORP**

(72)Inventor : **ISHIKAWA HAJIME**
NISHIDA TSUGUNORI
OBA HIROSHI
NISHIKAWA YOSHITAKA

(54) HIGH STRENGTH ROLLED PC STEEL BAR AND ITS PRODUCTION METHOD

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a high strength rolled PC steel bar having YS (0.2% proof stress) of ≥1,200 MPa, TS of ≥1,400 MPa and elongation of ≥4.5%.

SOLUTION: This high strength rolled PC steel bar consists of steel containing, by mass, 0.6 to 0.85% C and 1.0 to 3.0% Cr, in which the area ratio of ferrite having lamellar spacing of ≤0.1 μm is ≥80% and has YS (0.2% proof stress) of ≥1,200 MPa, TS of ≥1,400 MPa and elongation of ≥4.5%. The steel bar further contains 0.10 to 2.5% Si and 0.25 to 2.0% Mn and suitably contains one or more kinds of Al, Ti, Ca, rare earth metals, V and Nb and/or one or more kinds of B, Cu, Ni and Mo. A wire rod having the chemical composition is isothermally transformed at 450 to 650°C, is imparted with strain of ≤4%, and then is subjected to blueing treatment at 200 to 500°C for a holding time of 5 to 600 sec, thereby obtaining the objective steel bar.

CLAIMS

[Claim(s)]

[Claim 1] A high intensity rolling PC bar characterized by containing C:0.6 - 0.85%, and Cr:1.0-3.0%, for a pearlite 0.1 micrometers or less consisting [a lamellar gap] of 80% or more of steel at a rate of area, and for TS being [for YS (0.2% proof stress)] more than 1400 MPa more than 1200 MPa, and elongation being 4.5% or more in mass %.

[Claim 2] A high intensity rolling PC bar according to claim 1 with which said steel is further characterized by containing Si:0.10-2.5% and Mn:0.25-2.0% by mass %.

[Claim 3] A high intensity rolling PC bar according to claim 1 or 2 with which said steel is further characterized by containing one or more sorts (less than [aluminum:0.05%], Ti:0.005-0.05%, calcium:0.0005-0.005%, REM:0.0005-0.005%, V:0.002 - 0.5%, and Nb:0.005-0.1%) by mass %.

[Claim 4] A high intensity rolling PC bar according to claim 1, 2, or 3 with which said steel is further characterized by containing one or more sorts (B:0.0005 - 0.01%, Cu:0.05-1.0%, nickel:0.05-1.0%, and Mo:0.05-0.50%) by mass %.

[Claim 5] A manufacture method of a high intensity rolling PC bar which hot-rolls after heating slab which has a chemical entity concerning a high intensity rolling PC bar according to claim 1, 2, 3, or 4 to an austenite field, uses it as a wire rod, performs isothermal transformation at temperature of 450-700 degrees C, subsequently gives distortion of 4% or less further after that, and is subsequently characterized by performing bluing treatment by retention time amount for 5 - 600 seconds at temperature of 200-500 degrees C.

[Claim 6] A manufacture method of a high intensity rolling PC bar which hot-rolls after heating slab which has a chemical entity concerning a high intensity rolling PC bar according to claim 1, 2, 3, or 4 to an austenite field, uses it as a wire rod, and is characterized by performing isothermal transformation at temperature of 450-700 degrees C, and subsequently performing heat stretching processing further after that by temperature of 200-500 degrees C, and tension distortion of 4% or less.

[Claim 7] A manufacture method of a high intensity rolling PC bar which cools after reheating a wire rod which has a chemical entity concerning a high intensity rolling PC bar according to claim 1, 2, 3, or 4 to an austenite field, subsequently performs isothermal transformation at temperature of 450-700 degrees C, gives distortion of 4% or less further after that, and is subsequently characterized by performing bluing treatment by retention time amount for 5 - 600 seconds at temperature of 200-500 degrees C.

[Claim 8] A manufacture method of a high intensity rolling PC bar characterized by cooling after reheating a wire rod which has a chemical entity concerning a high intensity rolling PC bar according to claim 1, 2, 3, or 4 to an austenite field, performing isothermal transformation at temperature of 450-700 degrees C subsequently, and performing heat stretching processing further after that by temperature of 200-500 degrees C, and tension distortion of 4% or less.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] This invention relates to PC (prestress concrete) reinforcing bars used for the concrete pole, a concrete pile, etc., and its manufacture method.

[0002]

[Description of the Prior Art] Compressive force is given to concrete for improvement in rigidity and bending strength, and crack prevention, and there are PC pole and the PC pile which raised the reinforcement of the concrete pole and the concrete pile itself in the concrete pole and a concrete pile. And these are manufactured as follows.

[0003] First, a mild steel line is spirally twisted around the PC steel allotted to juxtaposition on the periphery (a "spiral muscle" is called below.), subsequently, the intersection of PC steel and a spiral muscle is fixed and the cylinder-like piece type reinforcement object of a basket (a "reinforcement object" is called below.) is manufactured. Next, this reinforcement object is introduced into a mold, the ends of the PC steel which constitutes a reinforcement object are fixed, and it is become tense by stress before and behind 70% of tensile strength. Subsequently, after it pours in concrete into a mold and concrete solidifies, stress stress is canceled of PC steel. Compressive force will be given to concrete by this discharge and PC pole or a PC pile is manufactured by it.

[0004] The PC wire specified to JISG3536 as the PC bar specified to JISG3137 as PC steel used for such the concrete structure can be mentioned as a typical thing. A PC bar carries out hardening annealing of the reinforcing bars which carried out after [hot rolling] air cooling, and is manufactured. TS (tensile strength) more than 1420 MPa specified by JISG3137 (D kind) is securable with this hardening annealing.

[0005] For example, in order to improve spot welding nature and a relaxation property, reducing Si, giving hardening annealing to the PC bar which added Mo, and manufacturing the high intensity PC bar more than TS:1420 MPa is indicated by the JP,3-151445,A official report. Thus, it is difficult for a PC bar to usually secure necessary uniform elongation and a necessary delayed fracture-proof property by this hardening annealing, since the organization of a PC bar turns into tempering martensitic structure although hardening annealing is given. For example, in the PC bar which has the tempering martensitic structure more than 1400 MPa, a delayed fracture-proof property deteriorates as shown in "iron and steel vol.81(1995).P1625."

[0006] On the other hand, as a PC bar which has an organization of those other than tempered martensite, hot rolling material is cold-worked and, subsequently the rolling PC bar which performed bluing treatment is offered. It is indicated by "prestressed concrete vol.13(1971) p.52" about this rolling PC bar by performing stretching and bluing treatment to the wire rod which hot-rolled the cast piece that the PC bar below TS1200 MPa can be manufactured.

[0007] In a rolling PC bar, while there is a point of having excelled [be / uniform elongation / high], YS (yield strength) is below 1100 MPa, and the actual condition is that high intensity-ization is not fully made. For this reason, the rolling PC bar which excelled [high intensity] in the delayed fracture-proof property more, and its manufacture method are searched for.

[0008]

[Problem(s) to be Solved by the Invention] Then, this invention makes it a technical problem to offer the manufacture method of tensile strength (TS) being the high intensity which has more than 1400 MPa, and manufacturing cheaply the high intensity rolling PC bar and this PC bar of high ductility by aging treatment, such as a heat stretch and bluing, without passing through usual PATINTINGU and a wire-drawing process.

[0009]

[Means for Solving the Problem] this invention persons examined an organization and a component of a hypoeutectoid or eutectoid steel, in order to solve the above-mentioned technical problem. For example, in order to make TS into proper reinforcement with steel of C 0.8%, isothermal transformation is performed and 80% or more of pearlite organization is required. However, TS is 1400MPa(s). Even if it is above, they are 1200MPa(s) about YS. It is difficult to

carry out above. It found out that for that it was necessary to set a lamellar gap to 0.1 micrometers or less. Generally, Cr is 1200MPa(s) about YS, although making a lamellar gap small and raising TS is known. It is necessary to add in order to carry out above. Moreover, they are 1200MPa(s) about YS, without carrying out those simple processings, if it is 0.05 micrometers or less although it has shown that lifting of YS is aimed at by a heat stretch etc. in this invention. The above reservation is also possible.

[0010] This invention solves the above-mentioned technical problem based on the above-mentioned knowledge, and the summary is as follows.

(1) A high intensity rolling PC bar characterized by containing C:0.6 - 0.85%, and Cr:1.0-3.0%, for a pearlite 0.1 micrometers or less consisting [a lamellar gap] of 80% or more of steel at a rate of area, and for TS being [for YS (0.2% proof stress)] more than 1400 MPa more than 1200 MPa, and elongation being 4.5% or more in mass %.

[0011] (2) A high intensity rolling PC bar of the above-mentioned (1) publication with which said steel is further characterized by containing Si:0.10-2.5% and Mn:0.25-2.0% by mass %.

(3) said steel -- further -- mass % -- less than [aluminum:0.05%] and Ti: -- a high intensity rolling PC bar of 0.005 - 0.05%, calcium:0.0005-0.005%, REM:0.0005-0.005%, V:0.002 - 0.5%, and the above (1) characterized by containing 0.005 - 0.1% of one or more sorts or Nb:(2) publication.

[0012] (4) said steel -- further -- mass % -- a high intensity rolling PC bar the above (1) characterized by containing 0.05 - 0.50% of one or more sorts, (2), or given in B:0.0005 - 0.01%, Cu:0.05-1.0%, nickel:0.05-1.0%, and Mo:(3).

[0013] Slab which has a chemical entity concerning a high intensity rolling PC bar the above (1), (2), (3), or given in (4) is hot-rolled after heating to an austenite field, and is used as a wire rod. (5) Subsequently A manufacture method of a high intensity rolling PC bar which performs isothermal transformation at temperature of 450-700 degrees C, gives distortion of 4% or less further after that, and is subsequently characterized by performing bluing treatment by retention time amount for 5 - 600 seconds at temperature of 200-500 degrees C.

[0014] (6) A manufacture method of a high intensity rolling PC bar which hot-rolls after heating slab which has a chemical entity concerning a high intensity rolling PC bar the above (1), (2), (3), or given in (4) to an austenite field, uses it as a wire rod, and is characterized by performing isothermal transformation at temperature of 450-700 degrees C, and subsequently performing heat stretching processing further after that by temperature of 200-500 degrees C, and tension distortion of 4% or less.

[0015] A wire rod which has a chemical entity concerning a high intensity rolling PC bar the above (1), (2), (3), or given in (4) is cooled after reheating to an austenite field. (7) Subsequently A manufacture method of a high intensity rolling PC bar which performs isothermal transformation at temperature of 450-700 degrees C, gives distortion of 4% or less further after that, and is subsequently characterized by performing bluing treatment by retention time amount for 5 - 600 seconds at temperature of 200-500 degrees C.

[0016] (8) A manufacture method of a high intensity rolling PC bar characterized by cooling after reheating a wire rod which has a chemical entity concerning a high intensity rolling PC bar the above (1), (2), (3), or given in (4) to an austenite field, performing isothermal transformation at temperature of 450-700 degrees C subsequently, and performing heat stretching processing further after that by temperature of 200-500 degrees C, and tension distortion of 4% or less.

[0017]

[Embodiment of the Invention] First, the chemical entity concerning the steel (steel of this invention) of the high intensity rolling PC bar of this invention is explained. C is more than TS:1400 MPa required as a PC bar, and YS:1200MPa, although it is an important and economical element in order to secure TS and YS. In order to obtain the above, respectively, it is required at least 0.6% or more, and required reinforcement is not obtained at less than 0.6%. Desirably, it is required 0.65% or more. On the other hand, if C exceeds 0.85%, network cementite or a big and rough cementite will deposit in a grain boundary, and ductile lowering will become remarkable in it. For this reason, C addition is made into 0.6 - 0.85%.

[0018] Cr is an element which raises hardenability, and the lamellar gap of a pearlite is made

Nb sludge, and raises the ductility of a rolling PC bar. For this reason, 0.005% or more needs to be added. However, since an effect is saturated and it becomes disadvantageous economically even if it adds so much, let 0.1% be a maximum. For this reason, Nb addition is made into 0.005 - 0.1%.
[0028] B is an element which hardenability is raised and raises the reinforcement of a rolling PC bar. Moreover, B is also the element which suppresses deterioration of delayed fracture through the grain boundary clarification effect which segregates to a grain boundary preferentially and controls grain boundary segregation, such as P, S, and Mn. For this reason, the minimum of B addition is made into 0.0005%. However, if it adds exceeding 0.01%, Fe23B will deposit and a delayed fracture-proof property will deteriorate. For this reason, B addition is made into 0.0005 - 0.01%.
[0029] Cu is an element added in order to raise hardenability. Moreover, Cu is also the element which generates a stable corrosion product, controls trespass of hydrogen, and improves delayed fracture. In order to acquire this effect, 0.05% or more needs to be added. However, if it adds exceeding 1.0%, since hot tearing will become easy to occur at the time of rolling, a maximum is made into 1.0%.
[0030] nickel is an element added like Cu in order to raise hardenability. Moreover, nickel is also the element which generates a stable corrosion product, controls trespass of hydrogen, and improves delayed fracture. Furthermore, nickel is an element which the effect which controls Cu embrittlement also does so. In order to improve a delayed fracture-proof property, 0.05% or more needs to be added. However, since the effect is saturated and becomes disadvantageous economically even if it adds exceeding 1.0%, a maximum is made into 1.0%.
[0031] Mo is an effective element in order to raise a relaxation property. In order to raise the reinforcement of steel, 0.05% or more needs to be added at least. However, if it adds exceeding 0.50%, since generation of a ferrite will be controlled, a maximum is made into 0.50%. Therefore, Mo addition is made into 0.10 - 0.50%.
[0032] In the above, the chemical entity of steel was explained. In a rolling PC bar, in order to secure YS more than 1200 MPa It sets after hot rolling to the wire rod which carried out air blast cooling, and is 1400MPa at least about TS. Although it is necessary to carry out above, to determine the amount of C, and the combination and addition of other consolidation elements in consideration of this, and to constitute the chemical entity of steel Next, the manufacture method (the manufacture method of this invention) of manufacturing the high intensity rolling PC bar of this invention is explained.
[0033] The feature of the manufacture method of this invention is a pearlite organization in the condition of not carrying out strong processing of wire drawing etc., and is 1200MPa(s) about YS. It is in the point considered as the above. That is, the pearlite organization in the steel of this invention has high ductility. TS is 1400MPa(s) as mentioned above. Except for the case where the amount of C is raised to 1.0% or more even if it was the DLP wire rod of the hypereutectoid steel secured above, if it remains as it is, they are 1200MPa(s) about YS. It is difficult to consider as the above. It sets to a wire rod [having given DLP to actual hypereutectoid steel], and TS is 1400MPa (s). When it is above, elongation is as low as about 7%, and when stretching + bluing treatment is performed, it has further a possibility that ductility may fall, by the age-hardening.
[0034] Then, this invention persons considered lifting of YS after performing after [stretching] bluing treatment, or heat stretch processing, and lowering of elongation after fracture that the above-mentioned technical problem should be solved, without performing wire drawing. And TS is 1400MPa(s). They are about 100 MPa(s) about YS by performing stretching + bluing treatment or heat stretch processing to the steel of the pearlite organization which has the above. It raised above and found out that lowering of elongation could be suppressed to about 2% or less.
[0035] From the above thing, the amount of C also sets to 0.6% or more of steel, and it is YS:1200MPa. It is TS:1400MPa above. It became possible easily to secure the above and 4.5% or more of elongation. Next, the organization and manufacture conditions of steel are explained. The feature of the steel of this invention is a pearlite subject's organization, and TS is 1400MPa(s). It is becoming the above. While for that satisfying the chemical entity mentioned above, it is required for 80% or more of pearlite organizations to exist, and it is characterized by obtaining a pearlite

of area of a pearlite. At T1-T11 of this invention steel, TS is 1400MPa(s). YS is 1200MPa(s) above. The above and E1 satisfied 4.5% or more. in addition, the steel H -- 10 and 11 are the examples which can secure reinforcement and ductility, without carrying out stretching + bluing.
[0043] Since steel H1-H3 was not a suitable steel component, a mechanical property was not securable. As for steel H1, predetermined reinforcement with few amounts of C is not obtained. Since steel H2 had few amounts of Cr(s), YS fell. Steel H3 is the example to which there are many Cr additions and ductility fell. In steel H4-H8, it does not become proper manufacture conditions and a construction material property is not acquired. In order that isothermal transformation temperature might not fill 80% or more of pearlite molar fraction with steel H4 low, reinforcement fell. Moreover, in steel H5, since isothermal transformation temperature is high, it is the example to which the lamellar gap of a pearlite became large and reinforcement fell. In steel H6, beforehand, the amount of distortion was high and ductility fell. Since bluing temperature is low and the steel H7 of diffusion of C is inadequate, it is the example from which the predetermined reinforcement of YS is not obtained. Bluing temperature is high and, as for steel H8, ductility fell by the age-hardening.
[0044]
[A table 1]

表1

	鋼	C	Si	Mn	P	S	Al	Ni	Cu	Cr	Mo	V	B	Ti	Ca	Nb	REM	A
本発明鋼	1	0.84	2.25	0.94	0.020	0.010	0.031	0.20		1.20							0.001	1.03
	2	0.84	2.35	1.89	0.010	0.005	0.004			1.40	0.20	0.10						0.90
	3	0.72	1.22	0.42	0.010	0.015	0.025		0.15	1.30				0.010	0.001			0.85
	4	0.78	0.25	0.90	0.005	0.007	0.002			2.10								0.95
	5	0.69	1.30	0.70	0.010	0.005	0.043			2.50			0.002	0.020				0.89
	6	0.80	0.90	0.35	0.010	0.002	0.005			1.05						0.020		0.90
	7	0.81	0.25	0.70	0.010	0.002	0.011	0.40	0.20	2.80	0.20	0.05	0.001	0.020				0.83
	8	0.77	1.00	0.70	0.001	0.001	0.022			1.50								0.91
	9	0.82	0.14	0.45	0.002	0.001	0.011			1.60				0.015				0.93
比較鋼	10	[illegible]	2.23	1.25	0.008	0.008	0.010			1.20			0.002					0.74
	11	0.62	0.24	0.30	0.007	0.007	0.028			[illegible]								0.67
	12	1.01	2.67	0.74	0.008	0.007	0.022			[illegible]								1.31

[0045]
[A table 2]

表2

	鋼	鋼	恒温変態温度 (℃)	パーライト分率 (℃)	ラメラー間隔 (μm)	予歪み (%)	ブルーイング温度 (℃)	ブルーイング時間 (s)	YS (MPa)	TS (MPa)	El (%)
本発明鋼	T1	1	600	94	0.06	1.5	250	180	1240	1510	6.3
	T2	2	550	88	0.06	3.0	300	180	280	1530	6.2
	T3	3	680	92	0.07	3.5	330	60	1230	1490	6.4
	T4	4	540	85	0.03				1320	1610	6.9
	T5	5	550	82	0.08	2.5	300	60	1330	1540	6.5
	T6	6	590	87	0.02				1390	1720	7.2
	T7	7	480	83	0.09	1.5	250	30	1280	1480	6.7
	T8	8	500	84	0.07	2.0	350	60	1310	1520	5.6
	T9	9	620	87	0.08	2.5	390	60	1220	1430	5.7
比較鋼	H1	10	525	72	0.08	2.2	275	240	[illegible]	[illegible]	10.4
	H2	11	525	87	[illegible]	2.2	275	240	1010	1530	[illegible]
	H3	12	525	88	0.07	2.2	275	240	1420	1820	[illegible]
	H4	1	[illegible]	[illegible]	0.02	2.2	275	240	[illegible]	[illegible]	6.2
	H5	2	[illegible]	62	[illegible]	2.2	275	240	[illegible]	[illegible]	5.3
	H6	5	525	93	0.08	[illegible]	275	240	[illegible]	1590	[illegible]
	H7	6	525	94	0.08	2.2	[illegible]	240	[illegible]	1850	[illegible]
	H8	7	525	85	0.07	2.2	[illegible]	240	1350	1590	[illegible]

[0046]
[Effect of the Invention] According to this invention, the rolling PC bar of high intensity can be manufactured and offered by low cost with high ductility. Therefore, this invention is industrial very useful.